A Comparative Study of Mohand and Laplace Transforms

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ABSTRACT: Mohand and Laplace transforms are very useful integral transforms for solving many advanced problems of engineering and sciences like heat conduction problems, vibrating beams problems, population growth and decay problems, electric circuit problems etc. In this article, we present a comparative study of two integral transforms namely Mohand and Laplace transforms. In application section, we solve some systems of differential equations using both the transforms. Results show that both the transforms are closely connected.

KEYWORDS: Mohand transform, Laplace transform, System of differential equations.

1.INTRODUCTION: In advance time, integral transforms[1-12] (Laplace transform, Fourier transform, Hankel transform, Mellin transform, Z-transform, Wavelet transform, Elzaki transform, Kamal transform, Mahgoub transform, Aboodh transform, Mohand transform, Sumudu transform, Hermite transform etc.) have a very useful role in mathematics, physics, chemistry, social science, biology, radio physics, astronomy, nuclear science, electrical and mechanical engineering for solving the advanced problems ofthese fields.

Many researchers [13-33] used these transforms and solve the problems of differential equations, partial differential equations, integral equations, integro-differential equations, partial integro-differential equations, delay differential equations and population growth and decay problems. Aggarwal et al. [34] used Mohand transform and solved population growth and decay problems. Aggarwal et al. [35] defined Mohand transform of Bessel's functions. Kumar et al. [36] used Mohand transform for solving linear Volterra integral equations of first kind.

Kumar et al. [37] used Mohand transform and solved the mechanics and electrical circuit problems. Solution of linear Volterra integral equations of second kind using Mohand transform was given by Aggarwal et al. [38]. Sathya and Rajeswari [39] used Mohand transform for solving linear partial integro-differential equations. Application of Mohand transform for solving linear Volterra integro-differential equations was given by Kumar et al. [40]. Aggarwal et al. [41] apply Laplace transform for solving population growth and decay problems.

In this paper, we concentrate mainly on the comparative study of Mohand and Laplace transforms and we solve some systems of differential equations using these transforms.

2. DEFINITION OF MOHAND AND LAPLACE TRANSFORMS:

2.1Definition of Mohand transforms:

In year 2017, Mohand and Mahgoub [6] defined "Mohand transform'' of the function $F(t)$for $t \geq 0$ as

$$M\{F(t)\} = v^2 \int_0^\infty F(t)e^{-vt}dt = R(v), k_1 \le v \le k_2$$

where the operator$M$ is called the Mohand transform operator.

2.2Definition of Laplace transforms:

The Laplace transform of the function $F(t)$for all $t \ge 0$ is defined as [7-11]:

$$L\{F(t)\} = \int_0^\infty F(t)e^{-st}dt = f(s)$$

where the operator L is called the Laplace transform operator.

The Mohand and Laplace transforms of the function$F(t)$ for$t \ge 0$ exist if $F(t)$ is piecewise continuous and of exponential order. These conditions are only sufficient conditions for the existence of Mohand and Laplace transforms of the function$F(t)$.

3. PROPERTIES OF MOHAND AND LAPLACE TRANSFORMS: In this section, we present the linearity property, change of scale property, first shifting theorem, convolution theorem of both the transforms.

3.1 Linearity property of Mohand and Laplace transforms:

a. **Linearity property of Mohand transforms [34-35, 38]:** If Mohand transform of functions $F_1(t)$ and $F_2(t)$are$R_1(v)$and $R_2(v)$ respectively then Mohand transform of $[aF_1(t) + bF_2(t)]$ is given by $[aR_1(v) + bR_2(v)]$, where a, b are arbitrary constants.
b. **Linearity property of Laplace transforms [41]:** If Laplace transform of functions $F_1(t)$ and $F_2(t)$ are $f_1(s)$ and $f_2(s)$ respectively then Laplace transform of $[aF_1(t) + bF_2(t)]$ is given by $[af_1(s) + bf_2(s)]$, where a, b are arbitrary constants.

3.2Change of scale property of Mohand and Laplace transforms:

a. **Change of scale property of Mohand transforms [35, 38]:** If Mohand transform of function $F(t)$ is $R(v)$ thenMohand transform of function $F(at)$is given by $aR\left(\frac{v}{a}\right)$.
b. **Change of scale property of Laplace transforms [7-11]:** If Laplace transform of function $F(t)$ is $f(s)$ thenLaplace transform of function $F(at)$is given by$\frac{1}{a}f\left(\frac{s}{a}\right)$.

3.3 Shifting property of Mohand and Laplace transforms:

a. **Shifting property of Mohand transforms [38]:** If Mohand transform of function $F(t)$ is $R(v)$ then Mohand transform of function$e^{at}F(t)$is given by $\frac{v^2}{(v-a)^2}R(v-a)$.
b. **Shifting property of Laplace transforms [7-11]:** If Laplace transform of function $F(t)$ is $f(s)$ then Laplace transform of function$e^{at}F(t)$is given by $f(s-a)$.

3.4 Convolution theorem for Mohand and Laplace transforms:

a. **Convolution theorem for Mohand transforms [38]:** If Mohand transform of functions $F_1(t)$ and $F_2(t)$ are $R_1(v)$ and $R_2(v)$ respectively then Mohand transform of their convolution $F_1(t) * F_2(t)$ is given by

$$M\{F_1(t) * F_2(t)\} = \frac{1}{v^2} M\{F_1(t)\} M\{F_2(t)\}$$

$\Rightarrow M\{F_1(t) * F_2(t)\} = \frac{1}{v^2} R_1(v) R_2(v)$, where $F_1(t) * F_2(t)$ is defined by

$$F_1(t) * F_2(t) = \int_0^t F_1(t-x)\, F_2(x) dx = \int_0^t F_1(x)\, F_2(t-x) dx$$

b. **Convolution theorem for Laplace transforms [7-11]:** If Laplace transform of functions $F_1(t)$ and $F_2(t)$ are $f_1(s)$ and $f_2(s)$ respectively then Laplace transform of their convolution $F_1(t) * F_2(t)$ is given by

$$L\{F_1(t) * F_2(t)\} = L\{F_1(t)\} L\{F_2(t)\}$$

$\Rightarrow L\{F_1(t) * F_2(t)\} = f_1(s) f_2(s)$, where $F_1(t) * F_2(t)$ is defined by

$$F_1(t) * F_2(t) = \int_0^t F_1(t-x)\, F_2(x) dx = \int_0^t F_1(x)\, F_2(t-x) dx$$

4. MOHAND AND LAPLACE TRANSFORMS OF THE DERIVATIVES OF THE FUNCTION $F(t)$:

4.1 Mohand transforms of the derivatives of the function $F(t)$ [34-35]:

If $M\{F(t)\} = R(v)$ then

a) $M\{F'(t)\} = vR(v) - v^2 F(0)$
b) $M\{F''(t)\} = v^2 R(v) - v^3 F(0) - v^2 F'(0)$
c) $M\{F^{(n)}(t)\} = v^n R(v) - v^{n+1} F(0) - v^n F'(0) - \cdots \ldots - v^2 F^{(n-1)}(0)$

4.2 Laplace transforms of the derivatives of the function $F(t)$ [7-11, 41]:

If $L\{F(t)\} = f(s)$ then

a) $L\{F'(t)\} = sf(s) - F(0)$
b) $L\{F''(t)\} = s^2 f(s) - sF(0) - F'(0)$
c) $L\{F^{(n)}(t)\} = s^n f(s) - s^{n-1} F(0) - s^{n-2} F'(0) - \cdots \ldots - F^{(n-1)}(0)$

5. MOHAND AND LAPLACE TRANSFORMS OF INTEGRAL OF A FUNCTION $F(t)$:

5.1 Mohand transforms of integral of a function $F(t)$:

If $M\{F(t)\} = R(v)$ then $M\left\{\int_0^t F(t) dt\right\} = \frac{1}{v} R(v)$

5.2 Laplace transforms of integral of a function $F(t)$ [7-11]:

If $L\{F(t)\} = f(s)$ then $L\left\{\int_0^t F(t) dt\right\} = \frac{1}{s} f(s)$

6. MOHAND AND LAPLACE TRANSFORMS OF FUNCTION $tF(t)$:

6.1 Mohand transforms of function $tF(t)$:

If $M\{F(t)\} = R(v)$ then $M\{tF(t)\} = \left[\frac{2}{v} - \frac{d}{dv}\right] R(v)$

6.2 Laplace transforms of function $tF(t)$[7-11]:

If $L\{F(t)\} = f(s)$ then $L\{tF(t)\} = (-1)\frac{d}{ds} f(s)$

7. MOHAND AND LAPLACE TRANSFORMS OF FREQUENTLY USED FUNCTIONS [6-11, 34-41]:

Table: 1

S.N.	$F(t)$	$M\{F(t)\} = R(v)$	$L\{F(t)\} = f(s)$
1.	1	v	$\frac{1}{s}$
2.	t	1	$\frac{1}{s^2}$
3.	t^2	$\frac{2!}{v}$	$\frac{2!}{s^3}$
4.	$t^n, n \in N$	$\frac{n!}{v^{n-1}}$	$\frac{n!}{s^{n+1}}$
5.	$t^n, n > -1$	$\frac{\Gamma(n+1)}{v^{n-1}}$	$\frac{\Gamma(n+1)}{s^{n+1}}$
6.	e^{at}	$\frac{v^2}{v-a}$	$\frac{1}{s-a}$
7.	$sinat$	$\frac{av^2}{(v^2+a^2)}$	$\frac{a}{s^2+a^2}$
8.	$cosat$	$\frac{v^3}{(v^2+a^2)}$	$\frac{s}{s^2+a^2}$
9.	$sinhat$	$\frac{av^2}{(v^2-a^2)}$	$\frac{a}{s^2-a^2}$
10.	$coshat$	$\frac{v^3}{(v^2-a^2)}$	$\frac{s}{s^2-a^2}$
11.	$J_0(t)$	$\frac{v^2}{\sqrt{(1+v^2)}}$	$\frac{1}{\sqrt{(1+s^2)}}$
12.	$J_1(t)$	$v^2 - \frac{v^3}{\sqrt{(1+v^2)}}$	$1 - \frac{s}{\sqrt{(1+s^2)}}$

8. INVERSE MOHANDAND LAPLACE TRANSFORMS:

8.1 Inverse Mohand transforms [34, 38]: If $R(v)$is the Mohand transform of $F(t)$then $F(t)$is called the inverse Mohand transform of $R(v)$and in mathematical terms, it can be expressed as

$F(t) = M^{-1}\{R(v)\}$, where M^{-1} is an operator and it is called as inverse Mohand transform operator.

8.2 Inverse Laplace transforms [7-11]: If $f(s)$ is the Laplace transforms of $F(t)$then $F(t)$is called the inverse Laplace transform of $f(s)$and in mathematical terms, it can be expressed as

$F(t) = L^{-1}\{f(s)\}$, where L^{-1} is an operator and it is called as inverse Laplace transform operator.

9. INVERSE MOHAND AND LAPLACE TRANSFORMS OF FREQUENTLY USED FUNCTIONS [7-11, 34]:

Table: 2

S.N.	$R(v)$	$F(t) = M^{-1}\{R(v)\} = L^{-1}\{f(s)\}$	$f(s)$
1.	v	1	$\frac{1}{s}$
2.	1	t	$\frac{1}{s^2}$
3.	$\frac{1}{v}$	$\frac{t^2}{2}$	$\frac{1}{s^3}$
4.	$\frac{1}{v^{n-1}}$	$\frac{t^n}{n!}, n \in N$	$\frac{1}{s^{n+1}}$
5.	$\frac{1}{v^{n-1}}$	$\frac{t^n}{\Gamma(n+1)}, n > -1$	$\frac{1}{s^{n+1}}$
6.	$\frac{v^2}{v-a}$	e^{at}	$\frac{1}{s-a}$
7.	$\frac{v^2}{(v^2+a^2)}$	$\frac{sinat}{a}$	$\frac{1}{s^2+a^2}$
8.	$\frac{v^3}{(v^2+a^2)}$	$cosat$	$\frac{s}{s^2+a^2}$
9.	$\frac{v^2}{(v^2-a^2)}$	$\frac{sinhat}{a}$	$\frac{1}{s^2-a^2}$
10.	$\frac{v^3}{(v^2-a^2)}$	$coshat$	$\frac{s}{s^2-a^2}$
11.	$\frac{v^2}{\sqrt{(1+v^2)}}$	$J_0(t)$	$\frac{1}{\sqrt{(1+s^2)}}$
12.	$v^2 - \frac{v^3}{\sqrt{(1+v^2)}}$	$J_1(t)$	$1 - \frac{s}{\sqrt{(1+s^2)}}$

10. APPLICATIONS OF MOHAND AND LAPLACE TRANSFORMS FOR SOLVING SYSTEM OF DIFFERENTIAL EQUATIONS:

In this section some numerical applications are give to solve the systems of differential equations using Mohand and Laplace transforms.

10.1 Consider a system of linear ordinary differential equations

$$\left.\begin{aligned} \frac{d^2x}{dt^2} + 3x - 2y = 0 \\ \frac{d^2x}{dt^2} + \frac{d^2y}{dt^2} - 3x + 5y = 0 \end{aligned}\right\} \quad (1)$$

with $x(0) = 0, y(0) = 0, x'(0) = 3, y'(0) = 2$ (2)

Solution using Mohand transforms:

Taking Mohand transform of system (1), we have

$$\left.\begin{aligned} M\left\{\frac{d^2x}{dt^2}\right\} + 3M\{x\} - 2M\{y\} = 0 \\ M\left\{\frac{d^2x}{dt^2}\right\} + M\left\{\frac{d^2y}{dt^2}\right\} - 3M\{x\} + 5M\{y\} = 0 \end{aligned}\right\} \quad (3)$$

Now using the property, Mohand transform of the derivatives of the function, in (3), we have

$$\left.\begin{aligned} v^2M\{x\} - v^3x(0) - v^2x'(0) + 3M\{x\} - 2M\{y\} = 0 \\ v^2M\{x\} - v^3x(0) - v^2x'(0) + v^2M\{y\} - v^3y(0) - v^2y'(0) - 3M\{x\} + 5M\{y\} = 0 \end{aligned}\right\} \quad (4)$$

Using (2) in (4), we have

$$\left.\begin{aligned} (v^2+3)M\{x\} - 2M\{y\} = 3v^2 \\ (v^2-3)M\{x\} + (v^2+5)M\{y\} = 5v^2 \end{aligned}\right\} \quad (5)$$

Solving the system (5) for $M\{x\}$and $M\{y\}$, we have

$$\left.\begin{aligned} M\{x\} = \frac{11}{4}\left[\frac{v^2}{(v^2+1)}\right] + \frac{1}{4}\left[\frac{v^2}{(v^2+9)}\right] \\ M\{y\} = \frac{11}{4}\left[\frac{v^2}{(v^2+1)}\right] - \frac{3}{4}\left[\frac{v^2}{(v^2+9)}\right] \end{aligned}\right\} \quad (6)$$

Now taking inverse Mohand transform of system (6), we have

$$\left.\begin{aligned} x = \frac{11}{4}sint + \frac{1}{12}sin3t \\ y = \frac{11}{4}sint - \frac{1}{4}sin3t \end{aligned}\right\} \quad (7)$$

which is the required solution of (1) with (2).

Solution using Laplace transforms:

Taking Laplace transform of system (1), we have

$$\left.\begin{aligned} L\left\{\frac{d^2x}{dt^2}\right\} + 3L\{x\} - 2L\{y\} = 0 \\ L\left\{\frac{d^2x}{dt^2}\right\} + L\left\{\frac{d^2y}{dt^2}\right\} - 3L\{x\} + 5L\{y\} = 0 \end{aligned}\right\} \quad (8)$$

Now using the property, Laplace transform of the derivatives of the function, in (8), we have

$$\left.\begin{aligned} s^2L\{x\} - sx(0) - x'(0) + 3L\{x\} - 2L\{y\} = 0 \\ s^2L\{x\} - sx(0) - x'(0) + s^2L\{y\} - sy(0) - y'(0) - 3L\{x\} + 5L\{y\} = 0 \end{aligned}\right\} \quad (9)$$

Using (2) in (9), we have

$$\left.\begin{aligned} (s^2+3)L\{x\} - 2L\{y\} = 3 \\ (s^2-3)L\{x\} + (s^2+5)L\{y\} = 5 \end{aligned}\right\} \quad (10)$$

Solving the system (10) for $L\{x\}$and $L\{y\}$, we have

$$\left.\begin{aligned} L\{x\} &= \frac{11}{4}\left[\frac{1}{(s^2+1)}\right] + \frac{1}{4}\left[\frac{1}{(s^2+9)}\right] \\ L\{y\} &= \frac{11}{4}\left[\frac{1}{(s^2+1)}\right] - \frac{3}{4}\left[\frac{1}{(s^2+9)}\right] \end{aligned}\right\} \quad (11)$$

Now taking inverse Laplace transform of system (11), we have

$$\left.\begin{aligned} x &= \frac{11}{4}sint + \frac{1}{12}sin3t \\ y &= \frac{11}{4}sint - \frac{1}{4}sin3t \end{aligned}\right\} \quad (12)$$

which is the required solution of (1) with (2).

10.2 Consider a system of linear ordinary differential equations

$$\left.\begin{aligned} \frac{dx}{dt} + y &= 2cost \\ x + \frac{dy}{dt} &= 0 \end{aligned}\right\} \quad (13)$$

with $x(0) = 0, y(0) = 1$ (14)

Solution using Mohand transforms:

Taking Mohand transform of system (13), we have

$$\left.\begin{aligned} M\left\{\frac{dx}{dt}\right\} + M\{y\} &= 2M\{cost\} \\ M\{x\} + M\left\{\frac{dy}{dt}\right\} &= 0 \end{aligned}\right\} \quad (15)$$

Now using the property, Mohand transform of the derivatives of the function, in (15), we have

$$\left.\begin{aligned} vM\{x\} - v^2x(0) + M\{y\} &= \frac{2v^3}{(v^2+1)} \\ M\{x\} + vM\{y\} - v^2y(0) &= 0 \end{aligned}\right\} \quad (16)$$

Using (14) in (16), we have

$$\left.\begin{aligned} vM\{x\} + M\{y\} &= \frac{2v^3}{(v^2+1)} \\ M\{x\} + vM\{y\} &= v^2 \end{aligned}\right\} \quad (17)$$

Solving the system (17) for $M\{x\}$and $M\{y\}$, we have

$$\left.\begin{aligned} M\{x\} &= \left[\frac{v^2}{(v^2+1)}\right] \\ M\{y\} &= \left[\frac{v^3}{(v^2+1)}\right] \end{aligned}\right\} \quad (18)$$

Now taking inverse Mohand transform of system (18), we have

$$\left.\begin{aligned} x &= sint \\ y &= cost \end{aligned}\right\} \quad (19)$$

which is the required solution of (13) with (14).

Solution using Laplace transforms:

Taking Laplace transform of system (13), we have

$$\left.\begin{aligned} L\left\{\frac{dx}{dt}\right\} + L\{y\} = 2L\{cost\} \\ L\{x\} + L\left\{\frac{dy}{dt}\right\} = 0 \end{aligned}\right\} \quad (20)$$

Now using the property, Laplace transform of the derivatives of the function, in (20), we have

$$\left.\begin{aligned} sL\{x\} - x(0) + L\{y\} = \frac{2s}{(s^2+1)} \\ L\{x\} + sL\{y\} - y(0) = 0 \end{aligned}\right\} \quad (21)$$

Using (14) in (21), we have

$$\left.\begin{aligned} sL\{x\} + L\{y\} = \frac{2s}{(s^2+1)} \\ L\{x\} + sL\{y\} = 1 \end{aligned}\right\} \quad (22)$$

Solving the system (22) for $L\{x\}$and $L\{y\}$, we have

$$\left.\begin{aligned} L\{x\} &= \left[\frac{1}{(s^2+1)}\right] \\ L\{y\} &= \left[\frac{s}{(s^2+1)}\right] \end{aligned}\right\} \quad (23)$$

Now taking inverse Laplace transform of system (23), we have

$$\left.\begin{aligned} x &= sint \\ y &= cost \end{aligned}\right\} \quad (24)$$

which is the required solution of (13) with (14).

11. CONCLUSIONS:

In this paper, we have successfully discussed the comparative study of Mohand and Laplace transforms. In application section, we solve systems of differential equations comparatively using both the transforms. The given numerical applications in application section show that both the transforms (Mohand and Laplace transforms) are closely connected to each other.

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